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ARDE-PORTLAND, INC.
100 WEST CENTURY ROAD
PARAMUS, NEW JERSEY

TECHNICAL PROGRESS REPORT NO. 2

QUARTERLY PERIOD: 11/13/62 - 2/13/63

FABRICATION OF A 65.5-INCH-DIAMETER SIMULATED ROCKET MOTOR CASE BY CRYOGENIC STRETCH-FORMING

PREPARED FOR:

United States Air Force
Contract AF 33(657)-9638

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Approved by: S. W. Henderson
Program Manager

TABLE OF CONTENTS

1.0 OBJECTIVE

To demonstrate the applicability of the cryogenic stretch-forming process to the fabrication of large rocket motor cases of heavy wall thickness. Previous work, under government contracts, has shown the feasibility of fabricating high-strength rocket cases by cryogenic stretch-forming. See references in appendix. Effort under the present contract is directed at "scaling up" the equipment and techniques to handle the size and wall thickness of a big-boost motor.

1.1 Specific Contract Tasks

1.1.1 Materials Evaluation

1.1.1.1 Welding Characteristics: Determination of welding characteristics of 1/4-inch and thicker 301 stainless steel plate.

1.1.1.2 Tensile Testing: Tensile tests of welded and unwelded coupon samples prior to and after cryogenic stretching in a bath of liquid nitrogen at -320°F. Specimens shall consist of coupons representing sections cut transverse (90°) and parallel to the rolling direction of the plate.

1.1.1.3 Hardness - strength correlation: Determine relationship between weld material hardness and strength characteristics. Weldments, unstrained, strained, and in the strained-and-aged conditions to be investigated.

1.1.1.4 Charpy Impact Tests: Testing of welded and unwelded specimens at room temperature and -320°F to obtain correlative data for notch sensitivity of the weld.

1.1.1.5 ASTM Center Notch Test: Testing of specimens in the unstrained, strained, and strained-and-aged conditions to obtain correlative data for notch sensitivity.

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1.1.2 Vessel Fabrication

1.1.2.1 Fabrication and testing of small-scale vessels, approximately 25 inches in diameter, to verify weld and dome forming techniques.

1.1.2.2 Design and procurement of a full-scale stretch-forming die to control cylinder roundness and straightness.

1.1.2.3 Fabrication and cryogenic stretching of a simulated rocket motor case, 65.5 inches in diameter, with a target strength level of 275,000 psi nominal hoop yield.

1.1.2.3.1 Hydrotest of stretched vessel to determine yield point.

1.1.2.3.2 Age - After hydrotest, the vessel will be aged-hardened to augment strength.

1.1.2.3.3 Hydroburst - Burst test to determine yield point and ultimate strength of the cryogenically stretched and age-hardened vessel.

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2.0 SUMMARY

Effort during the second 3-month period was directed toward design, procurement, and fabrication of test specimens, test equipment, vessel components, sub-scale and full-scale vessels.

2.1 Fabrication of 301 stainless steel specimens to be used in the material evaluation portion of the program was initiated. These include tensile, Charpy and notch tensile specimens.

2.1.1 Fabrication of the cryostat for the material evaluation phase was completed.

2.1.2 A sub-contract for test work in connection with the 301 stainless steel portion of the materials evaluation phase was placed with Thiokol Chemical Corporation/Wasatch Division.

2.1.3 301 stainless steel material evaluation test outline was initiated.

2.2 The full-scale stretch-forming die was received.

2.3 Sub-scale dog-bone shape preform components for forming elliptical heads were received.

2.4 Three simple sub-scale weld development vessels were fabricated and stretch-formed during this report period.

2.5 Fabrication of the first full-scale vessel, a simple unit, was initiated. The objective of this first full-scale vessel is to develop machining, handling, and welding techniques for the 65" size vessel.

2.6 A larger, more efficient cryogenic forming facility is near completion.

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3.0 COORDINATION WITH U.S.A.F.

3.1 Reports: Three monthly reports were submitted during the quarter as follows:

Monthly Progress Report No. 4	13 Nov. 1962	to	13 Dec. 1962
Monthly Progress Report No. 5	13 Dec. 1962	to	13 Jan. 1963
Monthly Progress Report No. 6	13 Jan. 1963	to	13 Feb. 1963

These reports were supplemented by informal letters and telephone conversations with the project officer.

3.2 Conferences

3.2.1 On 30 November 1962, at Wright Patterson Field, a program status conference was held between Air Force and ARDE-PORTLAND personnel. The following attended:

Lt. Col. L. E. Morse	A.F.	Development
Mr. B. Waters	A.F.	Program Manager
Mr. S.W.Henderson	A-P	Program Manager
Mr. R. Alper	A-P	Technical Director
Mr. A. J. Scarp	A-P	Field Representative

3.2.2 On the same date, Air Force and ARDE-PORTLAND personnel met to discuss materials for cryogenic stretch-forming applications. Attending were:

Mr. H. Zoller	A.F.	Materials
Lt. R. Dunco	A.F.	Materials
Mr. S.W.Henderson	A-P	Program Manager
Mr. R. Alper	A-P	Technical Director
Mr. A. J. Scarp	A-P	Field Representative

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4.0 DISCUSSION OF ACTIVITY

4.1 Sub-Scale Vessels

4.1.1 Weld Development: Weld schedules for sigma and sigma/heliarc-root welds were developed during the first quarterly period. During this second quarter, weld settings were developed in flat plate samples for a 2-pass heliarc weld. It was found that a somewhat smaller weld-prep could be used, resulting in a weld with less filler wire. Figure 1 shows the sigma weld-prep and the 2-pass heliarc weld-prep for comparison. The 2-pass heliarc weld has been developed as a back-up to the two earlier welds which are being evaluated in vessels.

In addition to the 2-pass heliarc weld, an all-sigma weld using 301 weld wire will be investigated. In the welding of austenitic stainless steels, it is a general practice to use Type 308 filler wire. The 308 chemistry is such that 8% to 10% delta ferrite is formed in the cast metal weld structure. The delta ferrite is ductile at high temperatures, whereas the austenitic structure tends to be brittle. The stresses set up by cooling from the welding temperature can thus induce "hot cracking" in the austenitic structure. The Type 308 filler metal, therefore, tends to resist the hot-cracking tendency by forming the more ductile delta ferrite. Welds in cryogenically stretch-formed vessels, however, are required to stretch a substantial amount, a fact which makes filler metal chemistry identical to parent metal chemistry most desirable. With the 308 filler wire, the weld tends to be too ductile during cryogenic stretching where it thins out to a greater extent than the parent metal. Because of this effect, weldments made with

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4.1.1 (Cont'd)

301 filler wire will be investigated. ARDE-PORTLAND's welds for cryogenic stretch vessels are made without chills or fixtures. For this reason, it is felt that hot cracking may prove to be no problem when the 301 weld wire is used. Procurement of a supply of the 301 wire was initiated during the report period. This weld wire is not commercially available, so that a longer-than-usual lead time will be required to melt and draw a small 301 heat. It should be noted that this approach is, again, a back-up to the welds currently being evaluated in vessels.

4.1.2 Vessel Tests: Sub-scale weld development Vessels #2100, #2101, #2102 were fabricated during the first quarter and were reported in the Technical Progress Report No. 1. During this second quarter, vessels #2103, #2104, and #2106 were fabricated and tested, also for weld development purposes.

4.1.2.1 Vessel #2103: This vessel was completed and cryogenically stretched in the second quarter. Its configuration utilized hemispherical end closures with sigma/heliarc-root welds. The longitudinal weld was not ground flush to the parent metal in this vessel. The vessel burst through the longitudinal weld at a 177,000 psi stress level (see Figure 2). This level was 50% less than that achieved with Vessel #2102, which was identical except for its longitudinal weld which was ground flush at the underbead. The success of #2102, as discussed in Quarterly Report No. 1, is explained on the basis that a "built-in-notch" was eliminated by the blending. Both the all-sigma and sigma/heliarc

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4.1.2.1 (Cont'd)

root welds in the .250-inch thickness, when left unblended, form notch-like junctures at the critical fusion zone where parent metal and weld metal intersect. Vessel #2103 failed through this juncture.

4.1.2.2 Vessel #2104: This vessel was fabricated utilizing pure-sigma welds. Both the underbead and over-bead were blended flush to the surface. Blending was utilized to eliminate any notch effect, such as evidenced in earlier tests. Vessel #2104 failure occurred through the longitudinal weld, during the stretch operation, at approximately 250,000 psi. Weld thinning was observed which raised the local stress in the weld to 320,000 psi. It can be seen that removal of the notches by blending is the key to reaching high stress levels with these welds. In the pure-sigma weld, the large amount of 308 filler added results in a weld which does not strain-harden rapidly enough during stretching. The strength of this weld would have held the vessel together, at parent metal design stress, if it had not thinned out excessively. Vessel #2106, with a weld blended in the same manner (over-bead and underbead), achieved a higher stress because the sigma/heliarc-root weld contained less 308 filler, strain-hardened more, and therefore thinned out less. This vessel is described below.

4.1.2.3 Vessel #2106: This vessel, which incorporated a blended sigma/heliarc-root weld, was stretched to burst. Failure occurred through the weld at approximately 275,000 psi. The failure was similar to that of Vessel #2104; but the longitudinal weld experienced less thin-out,

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4.1.2.3 (Cont'd)

resulting in higher over-all vessel stress at failure.

The completion of Vessels #2104 and #2106 represents a forward step in the weld development for .250"-thick material. The thin-out of the weld nugget during stretching limits the capability of the vessel. The weld material has adequate strength as evidenced by the local fracture stress in excess of 300,000 psi, but the reduction in section caused premature failure. Thin-out of the weld is attributed to the use of AISI 308 filler wire, which is more ductile than the 301 stainless steel parent material.

A vessel is currently being fabricated which utilizes a sigma/heliarc-root weld blended only at the underbead. This weld should stretch to about the same final thickness as the parent metal, and thus eliminate the premature weld failures.

4.2 Facilities and Tooling

4.2.1 Forming Die: To assure roundness and straightness, the full-scale 65.5-inch-diameter vessel will be stretched in a cylindrical die. The die was received from U. S. Steel Corporation during this report period and is a rolled-and-welded cylinder of stainless steel with a 3/8" wall thickness and 65.98-inch inside diameter. This diameter is designed to permit the vessel to "spring-back" to the desired 65.5-inch diameter when the stretching pressure is released.

4.2.2 Stretch Facility: A new ARDE-PORTLAND stretch facility designed to meet the requirements of larger vessels and higher stretch pressures is being erected. Almost all hardware

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4.2.2 (Cont'd)

has been received, and all major components are installed. The stretching pit will accommodate vessels of the 65.5-inch class and, by means of smaller tanks inserted in the pit, will accommodate vessels of smaller diameter. This facility will reach operational status during the next report period. Figure 3 shows the forming tank and the shed housing the cryogenic pumps. Note the small container installed in the forming tank for test runs on small vessels. The entire tank will be the liquid-nitrogen container for stretching the 65.5-inch cases. This insulated tank is permanently installed in the ground.

4.3 Materials Evaluation

4.3.1 Cryostat: Fabrication of the cryostat was completed during this report period. This is the unit which will facilitate testing of the tensile specimens at -320°F. As described in the previous quarterly report, the cryostat is comprised of a container for the liquid nitrogen, a clevis attachment for the tensile specimen, and a mechanism for inserting and retracting the clevis pin while under the liquid-nitrogen bath. At the close of this report period, the cryostat was being prepared for shipment to Thiokol/Wasatch Division. Contract negotiations were completed with Thiokol for performance of material evaluation tests. It was necessary to sub-contract this work because ARDE-PORTLAND does not have a tensile machine with the high load capability required for pulling the heavy specimens.

4.3.2 Material Specimens: Fabrication of the unwelded 301 tensile specimens has been initiated. Difficulty in shearing

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4.3.2 (Cont'd)

blanks from sheets was experienced which caused delay and will extend the fabrication cycle time. However, the first finished specimens are scheduled for delivery in the first week of March, with a continuous flow of delivered specimens into the month of April.

4.3.3 A test outline for the 301 stainless steel material program is being prepared. Each specimen will be identified by serial number, and the test outline will specify the evaluation required on each serialized specimen. This outline will be forwarded to Thiokol Chemical Corporation and to the Air Force project officer.

4.4 <u>Full-Scale Vessel</u>

4.4.1 The first 65.5-inch vessel consists of a cylinder with simple ASME-type closure heads. Based on the results of cryogenic stretching of sub-scale vessels, this vessel is being fabricated with sigma/heliarc-root welds with the underbead of the longitudinal weld ground flush to the inside diameter. The vessel is scheduled for completion during the next report period.

This unit is being fabricated to develop techniques and tooling for handling, machining, and welding of vessels of the 65.5-inch class. The intent is to detect and eliminate fabrication problems on a simple vessel where the investment is small. It is not anticipated that this vessel will be suitable for stretching.

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APPENDIX

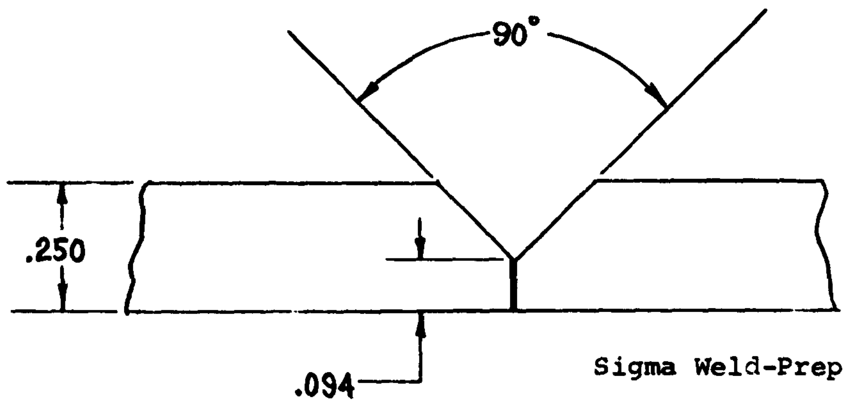
References

REFERENCES

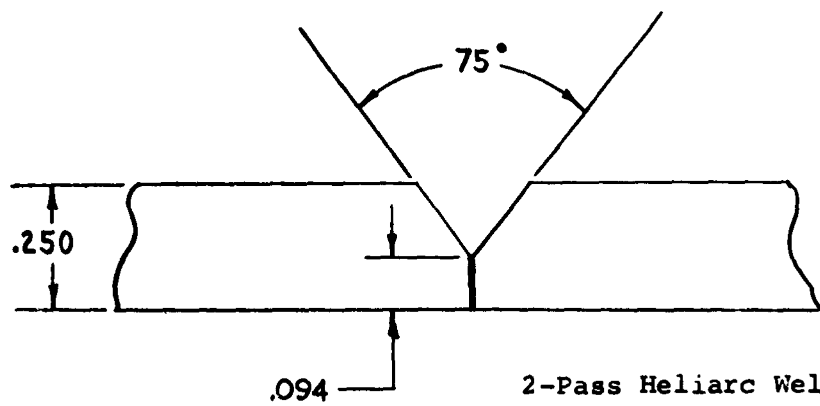
1. ARDE-PORTLAND final report, "Development of Ultra-High-Strength Rocket Motor Cases by Cryogenic Stretch-Forming", U. S. Army Ordnance Materials Research Office, Contract DA-30-069-ORD-3099 Task A, February 15, 1962.

2. ARDE-PORTLAND final report, "Cryogenic Stretch-Forming of Rocket Motor Cases", Navy Bureau of Weapons, Contract NOw 60-0263-C, May 15, 1961.

COMPARISON OF WELD PREPARATIONS
FOR SIGMA AND 2-PASS HELIARC



Sigma Weld-Prep



2-Pass Heliarc Weld-Prep

Figure 1

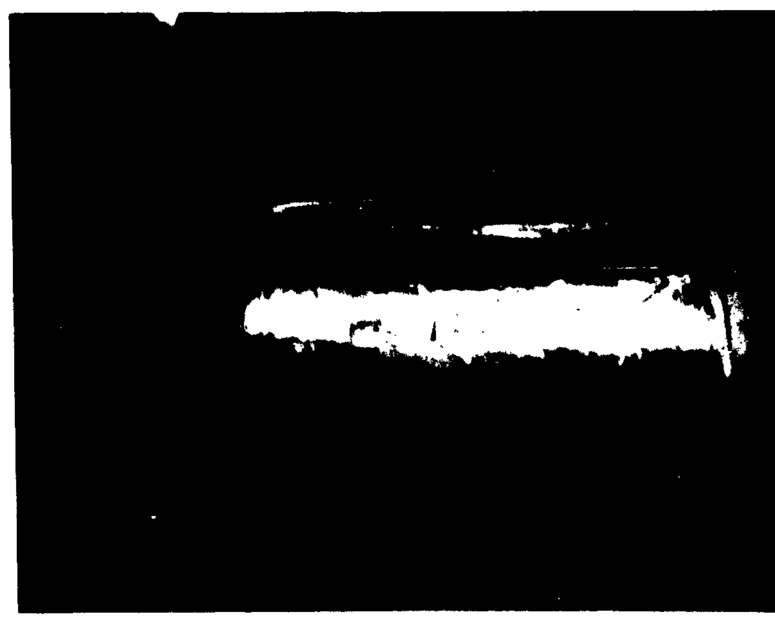


Figure 2 - Vessel #2103 after Burst

Figure 3 - View of New Facility Under Construction